International Journal of Sciences:
Basic and Applied Research
(IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Prevalence, Incidence and Severity of Anthracnose (*Colletotrichum* Spp) in Main Chili Growing Areas of Ethiopia

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Abstract

Chili anthracnose is the key constraint that hampers chili production in Ethiopia. But scientific information on the magnitude of the problem was not sufficient. Thus, this survey was aimed to assess the prevalence of chili anthracnose, weaknesses in management and formulate appropriate recommendations. 132 purposively selected chili fields, 106 farms and 26 nurseries throughout the chili livelihoods of Ethiopia had been surveyed. To evaluate the perceptions of farmers, semi-structured questionnaire had been used administered among 132 farmers. Data on incidence, severity and prevalence, and their variation across different locations, seasons and agro-ecological zones, had also been collected. The obtained data had been analysed through descriptive statistics using IBM SPSS 20.0. The highest and lowest disease spread was observed in Alaba and Shashogo with cumulative incidence of 41.88% and 19.81%, respectively. From the chili farms, the highest incidence was found in Arsi negelle followed by Alaba with the value of 31.66% and 28.66%, whereas the lowest incidence in farms was found in Humbo and Maraqo with 13.63% and 14.89%. Nurseries with a highest incidence had been observed in Humbo and Alaba with values of 13.5% and 13.02%, respectively. The disease incidence was low, 4.13% and 1.28%, in Shashogo and Arsi negelle.

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Prevalence was higher in upper-kolla agro-ecological zones where the mean was recorded as 21.82% and 7.55 in farms and nurseries. The mean incidence of farms was three times higher than nurseries. The spread of the disease was associated with non-hygienic practices in the nurseries as well as the disease inductive irrigation methods in use. Adequate chemical treatment, avoidance of water splashes, disinfection of tools and seedling, removal of sources of contaminations, were recommended to improve the practices in each field and nursery. Based on the information generated on the extent of anthracnose damage, the decision makers, policy experts and researchers will shift their prioritization and embark on controlling chili anthracnose in Ethiopia.

Keywords: Anthracnose; Chili; *Capsicum frutescence L.;* Incidence; Prevalence.

1. Introduction

Chili (*Capsicum frutescence* L.) is an agriculturally significant crop in most developing countries providing an important nutrient source and addresses food needs and job creation throughout the crop value chain [1,2]. The total area devoted to hot pepper is estimated 29% [3]. Hot pepper is the leading vegetable crop produced in the Ethiopia. The national production of green and dry hot pepper was 2,541,883.97 and 412,503.57 tones with average productivity of 66.88and 23.31tones ha respectively [4]. Thus, *Capsicum* productivity in Ethiopia is far below the world average that strongly demands immediate productivity improvement. People consume pepper for intake enhancement as well as to supplement the dietary needs. It is also one of the major income generating crops for most households of the pepper producing areas and plays a vital role in food security in Ethiopia [5]. World average green pepper productivity, on the other hand, was 15.5 t ha^{-1} compared to the pepper productivity in Ethiopia [6]. Thus, *Capsicum* productivity in Ethiopia is far below the world average that strongly demands immediate productivity improvement. This could be attributed mainly to absence of use of herbicides, lack of improved and good quality varieties, poor agronomic practices, poor disease and pest management, poor harvesting and post-harvest practices [7]. In spite of its importance, the hot pepper production system for green and dry pod has stayed as low input and low output with a national average yield of 7.6 t/ha for green pod whereas it was 1.6 t/ha for the dry pod, respectively [4], which is very low as compared to Thailand’s average national yield of hot pepper berries (15 t/ha) [8]. The decline of hot pepper production is attributed to poor varieties, poor cultural practices, the prevalence of fungal (blights) and bacterial as well as viral diseases [9]. This can be doubled or tripled through appropriate disease management coupled with good agricultural practices. According to Melaku and his colleagues [10] the present situation indicates that in the study area there is no improved hot pepper varieties but there is one local variety named “*Mita Mito*” by local growers, the green pod yield (3 ton per hectare) of this local variety is very low compared to national average yield. As a result, varietal information for the improvement of the crop for high fruit yield and quality in the existing agro-ecology is insufficient [11]. There has also been no research on evaluation of hot pepper which enables the growers to select the best performing varieties in the study area [10]. Assessments of Anthracnose disease are therefore one of the considerations to ease the existing problems of obtaining the desired varieties for which the output of this study was likely to assist and sensitize hot pepper growers and processors, furthermore the increasing demand for hot pepper to feed the growing human population and supply the ever-expanding pepper industries at national and international level has created a need for the expansion of pepper cultivation in to areas where it has not ever been extensively grown [12]. Assessment of the incidence and severity of plant diseases is important to determine the geographic distribution and status of the disease throughout a region in order to prioritize research themes to the situation [13, 14]. To get an accurate picture on the status of anthracnose disease, such studies must give due consideration to the impact of geophysical and associated climatic and edaphic variations between regions [1, 15]. However, most of the studies do not provide quantitative depth for disease incidence and severity in major paper growing parts of Ethiopia. On the other hand, such information is of key importance as it can be related to yield loss and hence economic impact of the disease [12, 13]. Thus, this study was initiated to (i) Identify causes of seedling mortality associated with observed chili anthracnose and leaf blackening symptoms, (ii) assess the extent of damage, (iii) identify weaknesses in management and (iv) formulate appropriate management recommendations.

2. Material and Methods

2.1 Experimental Site

This study was carried out in SNNP, Oromiya and Amhara regions, which are the most important pepper growing locations and characterized by range of dry to sub humid climate (Appendix 1 and 2). These locations are hot spot areas for anthracnose (*Colletotrichum* spp) [1]. The identification work was conducted in the Addis Ababa University, College of Natural and Computational Sciences, Department of Microbial, Cellular and Molecular Biology glass house in 2013.

2.2 Socio-Economic Survey

The survey was conducted in 132 farmers, 26 nurseries managers throughout the main chili producing regions of Ethiopia were interviewed during the period from Apr.-June, 2013. A two part questionnaire was used for farmers and nursery managers (Appendix 5). Both categories of informants were interviewed using the questionnaires with included photos of anthracnose symptoms on seedlings or shoots for easy identification. A photo of anthracnose disease symptoms was also included to facilitate disease recognition and thus making the communication easier and to determine for possible confusion with other diseases [13]. Other relevant information was noted during the survey, either in the form of additional notes, or as photographic records using a digital camera. Geographic position of the nurseries was also recorded using GPS software installed on Ipad Air 2. For some locations, the coordinates were downloaded through the computer software Google Earth, European technology [16].

2.3 Anthracnose Disease Assessments

132 hot pepper farms were visually assessed before and after flowering on permanent field. The distance between two nearby randomly surveyed fields per districts was 5 km. Assessments were carried out based on the method recommended by Mekonnen and his colleagues [16]; and Shiferaw and Alemayehu [1] in which, farms were visited diagonally, and the disease incidence was estimated by using 3 m x 3 m quadrant. The number of diseased plants and the total number in each quadrant were recorded. Disease incidence was calculated as the percentage of infected plants in each field at each location. On the other hand, anthracnose severity was assessed as the average leaf/fruit area covered by the symptom of anthracnose among the collected fruits infected with

anthracnose in each farm.

2.4 Spatial and Temporal Disease Distribution in a Nursery

The role of shedding (type and coverage), watering frequency and method were evaluated through the questionnaire and physical observations. Similarly, the possible role of the microclimate associated with either growth stage (age of the seedlings) or seedling density was also explored. Arising from observations during the survey, further experiments on the effect of seedling density and age on disease development were conducted. Notes on other factors that may facilitate disease spread in the nursery were also taken into consideration. These included handling of the seedlings, transmission routes and the movement of workers. Finally respondents were requested to provide information on temporal distribution of the disease [1].

2.5 Analysis of Data

Quantitative and qualitative data were all tabulated in Microsoft Excel. Disease incidence was computed for each sampled far, nursery and region, totals and means were tabulated. Geographic patterns of the disease prevalence were examined over the Regions, geographic position (GPS data) or agro-ecological zones [13, 14] by overlapping maps of the same scale. Statistical frequencies of particular answers, percentages, totals and or averages and respective standard deviations were computed accordingly. Data on temporal distribution of the disease were analyzed by highlighting in SPSS sheet on the location and respective period (months) of occurrence (SPSS IBM 20.0). Periods of high disease incidence were noted based on frequency of locations with infected seedlings. Similarly, locations of continuous occurrence of the disease were noted over the time.

3. Results

3.1 Anthracnose Disease Prevalence, Incidence and Severity

Out of the 106 selected farms and 26 nurseries surveyed, a total of 27, 28, 29, 30, 11 and 7 chili farms found in Wolaita zone, Hadiya zone, Gurage/Siltie zone, Oromiya and Amhara regions were assessed. Among these, none of the farms were completely free and the standard deviation among the location in prevalence, incidence and severity were 14.32, 12.54 and 20.95, respectively (Table 1).

In some nurseries, such as at Alaba district, the soil for seedlings is collected from near and under the roots of chili plant, up to 20 cm deep, after removal of superficial layer of dried fallen leaves. Because some of them have symptoms of anthracnose and infected leaf debris was occasionally passed onto seedling soil, there is a potential for transmission of viable saprophytic spores. The cumulative anthracnose incidence for SNNP Region was as high as 44.29% for transplanted seedlings while it was 42.5%. This was about as twice as the disease incidence recorded from Oromiya and Amhara Regions combined (Table 1). Anthracnose incidence means on mature plants as well as seedlings per Region, district and location surveyed are presented in Table 2. The overall mean incidence on transplanted-seedlings was higher (13.6 %) than that of direct planted ones (13.6 %) (Table 2).

Table 1: Prevalence Incidence and Severity of Chili seedlings in 132 farms in different regions, zones, kebelles, and locations of Ethiopia (Survey Conducted in 2013)

S. No.	District	No. of Fields Assessed	Mean Percent of Anthracnose disease:		
			Prevalence	Incidence	Severity
1	Humbo	4	70	37	70
2	Wolaita sodo Zuria	6	60	75	50
3	Mirab Abaya	8	100	50	50
4	Boditi (Damot Galle)	4	50	70	70
5	Areka	5	56	50	30
	Mean of Wolaita		67.2	56.4	54
1	Hossana zuria (Lemo)	6	100	70	70
2	Doisha	7	100	50	50
3	Shashogo	6	50	30	30
4	East Badawacho	4	75	40	40
5	Soro	5	50	50	50
	Mean of Hadiya		75	48	48
1	Mareko-Guraghe Borders	8	60	30	30
2	Qosha zuria	6	50	60	50
3	Butajira zuria	6	70	40	70
4	Meskan	4	70	75	70
5	Azernet-berbere	5	40	40	40
	Mean of Guraghe and siltie		58	49	52
1	Alaba	6	100	35	80
2	Sankura	7	80	70	75
3	Worabie zuria	8	80	75	70
4	Hadero	4	70	75	60
5	Mazoria	5	70	80	75
	Mean of KA		80	67	72
1	Adama-Wonji	4	40	40	14
2	Mojo-Ziway-Meki	4	30	30	13
3	Arsi negelle	3	40	10	14
4	Amhara-Bure	4	70	70	17
5	Amhara- Finoteselam	3	40	14	14
	Mean of Oromiya & Amh.		44	32.8	14.4
	Standard deviation		14.32	12.54	20.96

In a few farms and nurseries in Oromiya and SNNP Regions, seeds are deepen in to a solution of fungicides before sowing, but in most cases they are not. In one case, it was noted that seeded pots, were being sprayed with fungicide (Ridomil) even before seed germination. Very young seedlings, up to five leaf stage, in general, had no symptoms of anthracnose. At more developed stages of the seedlings, when most leaves are severely infected, the first four, at the bottom, tend to show minor expansion of necrotic area. Because this observation has led to the hypothesis of age related seedling tolerance to anthracnose, a specific trial was established.

Table 2: Percentage of anthracnose infected chili seedlings some selected Districts in Ethiopia (Survey Conducted in 2013)

District and SD	Infection(%) and Number of Seedlings Assessed		Total
	Transplanted	Planted	
Alaba	5194(13.02)	686(28.86)	5880(41.88)
SD	67.82	29.77	
Humbo	726(13.5)	477(13.627)	1203(27.17)
SD	7.9	5.04	
Maraqo	2987(5.48)	396(14.89)	3383(20.37)
SD	13.73	2.07	
Shashogo	2507(1.28)	340(18.53)	2847(19.81)
SD	2.74	1.87	
Arsi negelle	436(4.13)	139(31.66)	575(35.79)
SD	1	2.52	
Adama	534(7.87)	227(23.34)	761(31.21)
SD	7.02	2.37)	
Total	12384	2265	14649
Mean (%)	229.34	41.94	
SD	25.43	11.08	

Out of( ) = Total number of seedlings assessed; SD= Standard deviation

3.2 Infected mature plants and chili Gardens

For most nurseries (84.4%) there was at least one anthracnose infected chili at less than 5 kilometers distance. Coffee was occasionally used as shade for the seedlings within the nursery itself. Furthermore, comparison was made among nurseries and gardens, anthracnose incidence; under nurseries in a garden was 69.20% while under the 50% conventional polyethylene shedding, infected seedlings were less than 1%. Therefore, the role of these as source of inoculum was evident.

In general, seedlings placed nearby (approximately 1 meter diameter) were highly infected when compared to those located beyond. The chili plots were undersized and include Maraqo types that create a favorable condition for proliferation of anthracnose [14]. This suggests that the recommended integrated pest and disease management at the nursery [13, 14, and 17] must also be aimed at the nearby chili gardens and nurseries to avoid recurrent infestation.

Table 3: Anthracnose incidence means on Chili seedlings per regions, zones, kebelles, and locations of Ethiopia (Survey Conducted in 2013)

Order No.	Regions(Zones)	District and SD	Special location (Got)	Incidence on Seedlings (%)		
				Transplanted	Planted	Mean
1	SNNP, Alaba sp. wor	Alaba	A	36	100	68
2	SNNP, Alaba sp. wor	Alaba	B	42	3	22.5
3	SNNP, Alaba sp. wor	Alaba	C	28	14	21
4	SNNP, Alaba sp. wor	Alaba	D	34	11	22.5
5	SNNP, Alaba sp. wor	Alaba	E	56	21	38.5
		Mean		21.78	29.8	34.5
		SD		10.64	16.56	16.56
1	SNNP, Wolaita	Humbo	A	22	4	13
2	SNNP, Wolaita	Humbo	B	23	19	21
3	SNNP, Wolaita	Humbo	C	15	5	10
4	SNNP, Wolaita	Humbo	D	8	6	7
5	SNNP, Wolaita	Humbo	E	9	3	6
		Mean		8.56	7.4	11.4
		SD		7.02	6.58	6.03
1	SNNP, Guraghe	Mareko sp. dis.	A	12	5	8.5
2	SNNP, Guraghe	Mareko sp. dis.	B	2	9	5.5
3	SNNP, Guraghe	Mareko sp. dis.	C	41	6	23.5
4	SNNP, Guraghe	Mareko sp. dis.	D	25	4	14.5
5	SNNP, Guraghe	Mareko sp. dis.	E	36	8	22
		Mean		23.2	3.6	3.6
		SD		16.3	2.07	2.07
1	SNNP, Hadiya	Shashogo	A	12	6	9
2	SNNP, Hadiya	Shashogo	B	2	8	5
3	SNNP, Hadiya	Shashogo	C	41	7	24
4	SNNP, Hadiya	Shashogo	D	25	9	17
5	SNNP, Hadiya	Shashogo	E	36	8	22
		Mean		23.2	4.23	4.23
		SD		16.3	1.14	1.14
1	Oromiya, Lome	Arsi negelle	A	2	2	2
2	Oromiya, Lome	Arsi negelle	B	4	5	4.5
3	Oromiya, Lome	Arsi negelle	C	1	6	3.5
4	Oromiya, Lome	Arsi negelle	D	2	2	2
5	Oromiya, Lome	Arsi negelle	E	1	7	4

		Mean		2	4.4	3.2
		SD		1.23	2.3	1.15
1	Oromiya, East Shoa	Adama	A	3	2	2.5
2	Oromiya, East Shoa	Adama	B	2	5	3.5
3	Oromiya, East Shoa	Adama	C	1	8	4.5
4	Oromiya, East Shoa	Adama	D	5	9	7
5	Oromiya, East Shoa	Adama	E	4	6	5
		Mean		3	6	4.5
		SD		1.58	2.7	1.7
		Overall Mean		13.6	9.24	10.24
		Overall SD		6.7	5.8	6.06

NA=No plants available; SD= Standard deviation

3.3 Effect of Mulching on Anthracnose Diseases Incidence

Chili seedlings in Ethiopia are grown under different types of mulching material, arrangement or formats and density of coverage. In general, this investigation had found no evident impact of these variations on disease incidence. However, at Humbo - Tebela, where the 50% conventional grass mulching was combined with sprinkle aerial irrigation, high level of disease prevalence and mortality was observed. This was enhanced by the presence of infected chili branches just above the mulching net (Figure 1).

Figure 1: Variability of Shading and mulching constructions in Chili nurseries: Humbo, Ethiopia, 2013.

3.4 Effect of Watering on Anthracnose Diseases Incidence

According to MoARD [18], the potential irrigable land in Ethiopia is between 3.7 and 4.3 million hectares but the actual irrigated area is estimated at just 7-10% of this. Of this area approximately 55% is traditional irrigation schemes, 20% is modern small-scale, and 25% is medium and large-scale irrigated commercial farms (private and state-owned). Adoption of pond technology for small-scale irrigation is, however, not uniform across the country. In a few areas such as of SNNPR (Alaba Special Woreda), East shoa zones of Oromia (especially Adama District) and the neighboring Lome districts of West Arsi Zone Beyene and his colleagues [2]. Motorized pumps are often used to lift water from rivers, lakes, ponds or hand-dug wells when gravity irrigation is difficult. They are typically used for high-value crops in Zeway, Dugda in Oromia. The finding of this study strengthens this reality (Figure 2).

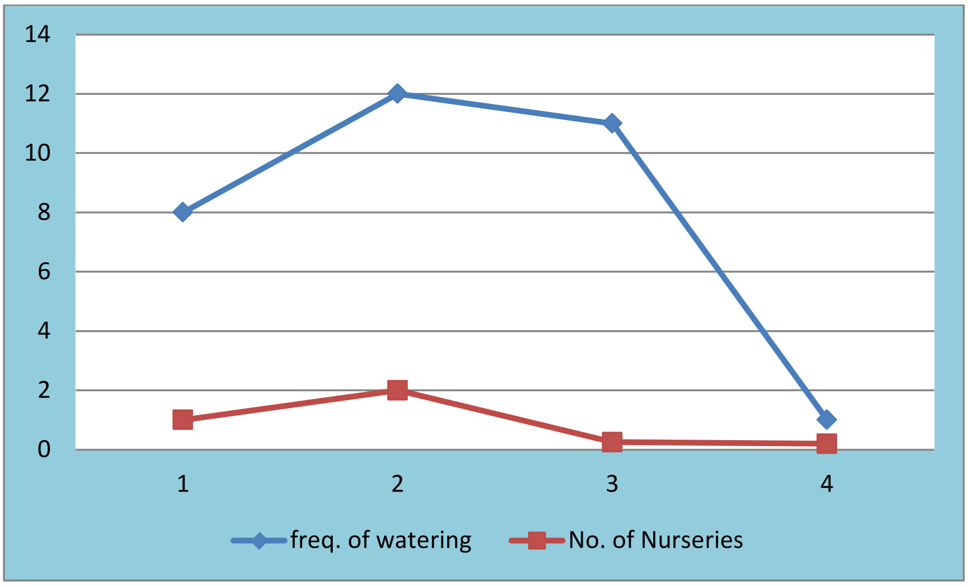

Figure 2: Number of nurseries that implement varying watering scheme in chili growing areas of Ethiopia, 2013

3.5 Effect of Agro-ecological Zones on spatial variations of anthracnose

The result showed variation exists across locations in the study areas. The overall mean of incidence Alaba, was lower than Maraqo with 35.7 and 38.8, respectively. The highest mean incidence, 41.4%, was observed in Shashogo.

However, incidence of the two representative areas, viz., Arsi negelle and Adama, was 53.75 and 47.5. This implies prevalence was higher in Oromiya than SNNP. Ethiopia is divided into 32 agro-ecological zones delineated by biophysical conditions [19] (MoA, 2000) (Appendix 2) which are significantly influenced by altitude, which ranges from -155 to + 4,000 meters above sea level [2].

Rain-fed agriculture dominates in Ethiopia. However, rainfall distribution and intensity vary spatially, tending to decrease from southwest to northeast (Beyene and his colleagues [2] (2010). Rainfall also varies temporally resulting in incidents of drought every 4-5 years (Osman and Sauerborn 2008).

These rainfall patterns affect crop and livestock production and contribute to volatility in food prices, which ultimately affects overall economic development (FAO 2009). Subsistence farming is a typical feature of agriculture in Ethiopia. The midlands and highlands are dominantly characterized as mixed farming systems [2]

(Beyene and his colleagues (2010).

Table 4: Anthracnose incidence means on Chili seedlings in different Agro-ecological zones, Seasons and locations in some selected areas of Ethiopia

Agro-Ecological Zone	Order No.	District and SD	Kebelle	Special location (Got)	Mean Incidence on Seedlings (%)		
					On-season	Off-season	Overall
Upper Kolla	1	Alaba	Keb.1	1	93	10	51.5
Upper Kolla	2	Alaba	Keb.2	2	52	13	32.5
Upper Kolla	3	Alaba	Keb 3	3	32	16	24
Upper Kolla	4	Alaba	Keb.4	4	42	17	29.5
Upper Kolla	5	Alaba	Keb. 5	5	57	25	41
		Mean			55.2	16.2	35.7
		SD			23.21	5.63	10.76
Upper kolla	1	Humbo	Keb.1	1	27	14	20.5
Upper Kolla	2	Humbo	Keb.2	2	33	19	26
Upper Kolla	3	Humbo	Keb 3	3	35	15	25
Upper Kolla	4	Humbo	Keb.4	4	28	16	22
Upper Kolla	5	Humbo	Keb. 5	5	19	13	16
		Mean			28.4	15.4	21.9
		SD			6.23	2.31	3.97
Woyina Dega	1	Maraqo	Keb.1	1	52	25	38.5
Woyina Dega	2	Maraqo	Keb.2	2	62	29	45.5
Woyina Dega	3	Maraqo	Keb 3	3	51	16	33.5
Woyina Dega	4	Maraqo	Keb.4	4	55	14	34.5
Woyina Dega	5	Maraqo	Keb. 5	5	66	18	42
		Mean			57.2	20.4	38.8
		SD			6.53	6.35	5.04
Upper Kolla	1	Shashogo	Keb.1	1	72	16	44
Upper Kolla	2	Shashogo	Keb.2	2	56	18	37
Upper Kolla	3	Shashogo	Keb 3	3	67	17	42
Upper Kolla	4	Shashogo	Keb.4	4	75	19	47
Upper Kolla	5	Shashogo	Keb. 5	5	56	18	37
		Mean			65.2	17.6	41.4
		SD			8.871	1.141	4.39
Upper Kolla	1	Arsi negelle	Keb.1	1	72	22	47
Upper Kolla	2	Arsi negelle	Keb.2	2	54	50.5	52.25

Upper Kolla	3	Arsi negelle	Keb 3	3	71	66	68.5
Upper Kolla	4	Arsi negelle	Keb.4	4	82	12	47
Upper Kolla	5	Arsi negelle	Keb. 5	5	81	27	54
		Mean			72	35.5	53.75
		SD			11.24	22.14	8.82
Upper Kolla	1	Adama	Keb.1	1	73	22	47.5
Upper Kolla	2	Adama	Keb.2	2	82	25	53.5
Upper Kolla	3	Adama	Keb 3	3	61	28	44.5
Upper Kolla	4	Adama	Keb.4	4	55	29	42
Upper Kolla	5	Adama	Keb. 5	5	64	36	50
		Mean			67	28	47.5
		SD			10.61	5.24	4.51
		Overall Mean (%)			57.5	22.18	39.84
		Overall SD			6.27	7.63	2.83

SD= Standard deviation

3.6 Effect of Agro-ecological Zones on Temporal Distribution of Anthracnose

As indicated in Table 5, Incidence of chili anthracnose in nurseries over time showed that the disease was predominantly prevalent from October, 2013 to January, 2014. During off-season, the highest mean of incidence was observed in Arsi negelle, Adama, Shashogo, Maraqo, and Alaba with incidence of 72, 67, 65.2, 57.2 and 55.2, respectively. During the on-season of the same year the incidence was shown to be lower with incidence of 35.5, 20.4, 17.6, 16.2 and 15.4 percent in Arsi negelle, maraqo, shashogo, Alaba and Humbo, respectively. There was a significant variation among the nurseries in terms of anthracnose incidence in which Alaba showed 23.2 during off-season. The standard deviation was 22.14 during the on-season of 2013 in Arsi negelle. From the two main chili growing regions, SNNP and Oromiya, the disease incidence was reported to be higher in Oromiya region. In SNNP, the disease prevalence was confined only between June and September. Anthracnose prevalence over different agro-ecological zones indicates that regardless of the agro-ecological zone, the disease appears consistently between June and July. In Upper Kolla, the disease occurred throughout the year depending on the nursery. In Woyina Dega, anthracnose incidence was observed between June - August while in Kolla it occurred only over a short period June – July (Table 5).

3.7 Perceptions on the Intensity of Anthracnose

Most interviewees (98.8%) responded to have noticed anthracnose symptoms from some of the seedlings during preparation and collection of seeds. In one extreme scenario at Shashogo district, there was a reference that it would be hard to find a single farm that is completely free from anthracnose symptoms. The workers involved in preparation associated the disease with poor quality of (84.5%), meaning reduction of success at (60.5%) or transmitting the disease on seedlings (10.0%) and others did not know the effect (6.6%). Workers at the nursery believe that anthracnose caused damage to seedlings (92.0%). Among these, 38.0% admitted that defoliation is the only damage observed while other 32% reported that severe infection could cause mortality of seedlings. Other respondents (40%) believe that the disease disappears or declining because they spray the seedlings immediately after transplanting, thus, never experienced a severe disease damage.

3.8 Perception on Infected Seedlings

Handling of seedlings at the nursery in general includes physical contact between seedlings regardless of their pathological status. But just prior to transplanting, most of the infected leaves are detached so that only the four basal ones are left. General nursery hygiene varied from one place to another. In some, the capes and other seedling debris are dispersed on walking paths between the seedlings in other nurseries such materials are piled and buried or re-used leaving the nursery completely clean. In general non-hygienic nurseries had high levels of disease prevalence.

3.9 Perceptions on the Management

As indicated in the Appendix 3, most farmers and nursery managers were not following the recommended fungicides application schemes. The types of fungicides applied for anthracnose management in each nursery are presented in Appendix 3. Four active molecules of different families were used at variable frequencies and concentrations depending on location throughout the main chili growing areas of Amhara, SNNP and Oromiya regions in the country. Mancozeb is applied between 0.5 and 3.5 g/l, flint between 1.5 and 25 g/l, volcano between, 0.5 and 8.5 ml/l. In most nurseries, fungicides are applied upon the appearance of the first symptoms. Only one case (Arsi negelle District and Batu: Ziway) was recorded with continuous preventive applications of Volcano. It was observed, however, that application of fungicides is sometimes immediately followed by irrigation.

4. Discussions

The finding this ground-breaking anthracnose surveys conducted on chili farms and nurseries in Ethiopia indicated that the incidence of anthracnose disease in five different farms of Alaba district ranges between 34% and 56%; and 3% and 100%. In the same district, incidence of diseases on transplanted and directly planted seedlings were 21.78 and 29.8 percent, respectively. The overall mean of these five locations in Alaba district was 34.5%.

In Shashogo district, anthracnose incidence in transplanted seedlings ranged between 2% and 41% while 7% and 9% in planted seedlings. The overall disease anthracnose incidence was 5% and 24%. It was confirmed that the wide distribution of disease throughout the country and provided evidence that SNNP had the highest prevalence of the disease. Probably because the disease is known to be more severe under moderate humid and moderately warm conditions [13]. SNNP is one of the most chili-conducive regions in the country [1]. The peak of disease was reported to be from January to April. This period coincides with the most rainy and humid period in all parts of the country [15].

In Maraqo district, the lowest and highest incidence in transplanted seedlings was 2% and 41% and 4% and 9%

incidence was observed in planted seedlings. The overall range of anthracnose incidence was 5.5% and 23.5% for transplanted and planted seedlings. Teklay and his colleagues [13] indicated that 93.7%, 84.8%, 88.6%, 37% and 58% of sorghum fields were infected by anthracnose, leaf blight, long smut, head and loose smuts, and downy mildew, respectively. This indicated that sorghum is suffered from complexes of diseases. The incidence and severity of the former diseases were 69.9% and 53.01%, 55.9% and 38.7%, 23% and 77.2%, 1.9% and 71.7%, and 43.6% and 41%, respectively. Most of the cultivated farmers' cultivars sown were susceptible at least to one disease putting large area of sorghum production at threat.

In Humbo, the highest and lowest anthracnose incidences were 23% and 8% in transplanted seedling and 19% and 3% on planted seedlings. The total incidence of anthracnose disease ranges between 6% and 21%. The overall mean of incidence of both transplanted and planted seedlings in Humbo district was 11.4%. Anthracnose incidence on chili farm is estimated between 31.66%, 28.86%, 23.34%, 18.53%, 14.89% and 13.63% in Arsi negelle, Alaba, Adama, Shashogo, Maraqo and Humbo, respectively. But significant variation is found in terms of anthracnose damage on chili seedlings. In this study, revealed up to 41% incidence was exhibited. There were no data available on extreme cases of disease incidence because control actions are usually taken immediately after the disease epidemics initiation.

Yohannes and his colleagues [15] had carried out field surveys and the findings revealed the prevalence of anthracnose in all the locations. However, both disease incidence and severity varied markedly across the locations. Both incidence and severity of avocado and papaya anthracnose were found to be highest in Wondo Genet (45 and 22% for avocado and 39.7 and 22% for papaya, respectively) followed by Wolaita (32.4 and 16.8% for avocado and 36 and 16.6% for papaya, respectively). However, both anthracnose incidence and severity of *C. gloeosporioides* were lowest at 23.99% on avocado and 31.8% papaya and 13.33% on avocado and 13.67% on papaya, respectively, in Ziway [15].

In Arsi Negelle, the maximum disease incidences in transplanted and planted seedlings were 4% and 7% while the minimum anthracnose incidence were 1% and 2%, respectively. The overall incidence of the five localities ranged between 2% and 4.5%. This corroborates the results obtained by Shiferaw and Alemayehu [1] in which 55% of seed beds were infected by seedling diseases. The highest seedling infection (73%) was recorded at Hawassa zuria district followed by Halaba, Lanfro and Dalocha districts (60, 56 and 54%, respectively). Similarly survey results made after transplanting showed that 229 (75 %) of samples were infected at least by one disease. In the same way, survey results of Shiferaw and Alemayehu [1] made after transplanting showed that 229 (75 %) of samples were infected at least by one disease. The frequency of pathogen growth depicted that 30% of the associated pathogens were different bacteria, while 21%, 12%, 9% and 3.0% belong to the fungal genera *Fusarium* spp, *Colletotrichum* spp, *Cercospora* spp and *Alternaria* spp respectively.

In Adama, the overall mean of anthracnose incidence was 4.5%. Planted seedlings, having value of 6% and 3%, were found to have as twice higher incidence as transplanted ones. Increased rate of success after treating the seedlings with a fungicide has been observed by the informants. It may be due to fungicide action against other microorganisms or endophytic pathogen. Adoption analysis of previously recommended cultural practices showed 100%, 42%, 31%, 30% and 19% for fertilizer application, engagement in two year rotation, row planting, use of pesticides and improved seed, respectively [1, 12].

The role of soil and seeds in disease transmission was not evident. However, in Brazil, under laboratory conditions, Lopez and Lucas [20] observed that 33% of seedlings emerging from untreated Chili seeds had necrotic lesions on cotyledons, hypocotyls or epicotyls and associated these with a wide range of fungi that can saprophytically survive on seeds. Thus, although the need for seed treatment would be better justified through a prior seed testing by a specialized laboratory, preventive measures are sometimes simply not taken due to economic or technical limitations.

Seedlings placed under or close to infected Chili had shown increased disease prevalence. Evidence of this was found; therefore, this practice should be avoided. Incidence of anthracnose on mature seedlings was almost six times than on young seedlings because of damper microclimate in highly dense arrangement of old plants. In addition, removal of infected leaves, during the process, reduces the probability of plant-to-plant transmission. Findings from this survey may suggest that matured or old seedlings do not necessarily transmit the *Colletotrichum* spp. to seedlings. The main reason for this could be that infected seedlings may have died long before sprouting and thus not assessed during the study. Subsequent infections on adjacent seedlings may be coming from other aerial sources [21, 22].

5. Conclusions

There is high prevalence and severity of leaf anthracnose in the study area. The survey result also cognizant of the disease as widely distributed in Ethiopia and therefore the need for fungicide control was recommended. Precautionary measures, management strategies and attitudes of the nursery workers regarding the disease were variable. There were discrepancies among the nurseries in terms of cleanliness and management. Farmers lack appropriate guidance and training. Therefore, it would be important to produce a manual on chili seedling pests and disease management and use it in a nationwide training program for chili producers.

Acknowledgement

The authors thank the Addis Ababa University and Wolaita Sodo University for their support.

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Appendices

Appendix 1. General characteristics of trial sites from which anthracnose disease incidence and severity data had been collected in 2013

Table 5

Trial Name	Latitude	Longitude	Altitude(m)	Region/Zone	AE Zone	Time
Addis Ababa						
AAU, 4kilo	9.037354	38.76779	2435.84	Addis Ababa	6	2013 -07-20
Hadiya						
Doisha	7.473552	38.4449	1900.00	Hadiya, SNNPR	1	2013 -09-20
Hossana	7.552825	37.85649	2309.44	Hadiya, SNNPR	2	2013 -08-01
Bonosha Mazoriya	8.042378	38.49944	1840.08	Hadiya SNNPR	3	2013 -08-08
East Badawacho	7.417574	38.19376	1774.78	Hadiya, SNNPR	1	2013 -08-17
Soro	8.142378	38.59944	1840.08	Hadiya SNNPR	3	2013 -08-18
Gurage & Siltie						
Sankura	7.353447	38.09112	1823.63	Silti, SNNPR	5	2013 -09-8
Sankura	7.353447	38.09112	1823.63	Silti, SNNPR	3	2013 -09-10
Worabe	7.737333	38.12154	1988.49	Silti, SNNPR	2	2013 -09-09
Alkeso	7.848471	38.18766	2096.36	Silti, SNNPR	4	2013 -09-18
Menaheria	7.918454	38.23706	2306.69	Silti, SNNPR	6	2013 -10-24
Qibet	7.949281	38.26793	2389.2	Gurage, SNNPR	3	2013 -09-21
Mareko-Guraghe Borders	8.024675	38.32799	2120.24	Mareko, SNNPR	3	2013 -10-22
Qoshe Fields	8.01513	38.53197	1872.82	Mareko, SNNPR	4	2013 -10-20
Butajira zuria	7.918454	38.23706	2306.69	Butajira, SNNPR	6	2013 -10-25
Meskan	7.949281	38.26793	2389.2	Butajira, SNNPR	3	2013 -10-23
Azernet-berbere	7.918454	38.23706	2306.69	Silti, SNNPR	6	2013 -10-24
Wolaita						
Wolaita Sodo	6.852763	37.76414	1997.79	Wolaita, SNNPR	3	2013 -09-11
Humbo Tebella	6.703099	37.7751	1590.79	Wolaita, SNNPR	4	2013 -09-12
Mirab Abaya	6.652763	37.76414	1997.79	Gamogofa, SNNPR	2	2013 -09-13
Boditi (Damot Galle)	7.703099	37.7751	1590.79	Wolaita, SNNPR	4	2013 -09-14

Areka	7.852763	37.76414	1997.79	Wolaita, SNNPR	2	2013 -09-16
Kambata & Alaba						
Halaba Field A	7.317574	38.09376	1774.78	Alaba, SNNPR	6	2013 -11-07
Halaba Field B	7.389356	38.1042	1825.77	Alaba, SNNPR	3	2013 -11-08
Hadero	7.989356	38.4042	1825.77	Kambata, SNNPR	3	2013 -11-09
Mazoria	7.889356	38.3042	1815.00	Kambata, SNNPR	3	2013 -11-10
Oromiya						
Wonji	8.4538411	39.280399	- -	Adama, Oromiya	2	2013 -10-20
Adama zuria	8.5263486	39.2583293	- -	Adama, Oromiya	2	2013 -10-20
Arsi Negelle	7.3610886	38.668713	- -	W. Arsi, Oromia	1	2013 -10-22
Nekemte	9.0893009	36.555386	- -	W.wolega oromia	1	2013 -10-27
Gute	9.3208484	36.671451	- -	W.wolega Oromia	3	2013 -10-27
Ano	9.0928759	36.959483	- -	W.wolega Oromia	2	2013 -10-28
Bako	9.1248249	37.0588169	- -	W.wolega Oromia	2	2013 -10-29
Amhara						
Bure	10.708145	37.0668651	- -	E.Gojam, Amhara	3	2013 -10-15
Finote-selam	10.697988	37.176773	- -	E.Gojam, Amhara	2	2013 -10-15

Appendix 2. Map of Agro-ecological zones (R1 to R6). Source: NMA

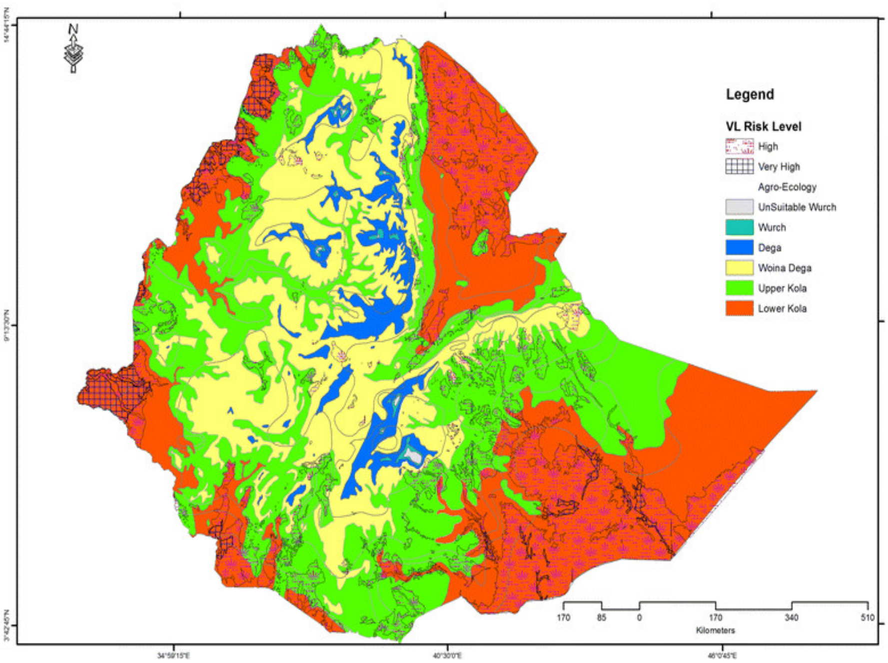

Figure 3

Appendix 3. Fungicides applied on Chili seedlings in different regions, zones, kebelles, and locations of

Ethiopia (Survey Conducted in 2013)

Table 6

Order No.	District and SD	Kebelle	Special location (Got)	Insecticide			Interval (days)*
				Fungicide Name	Active Ingredient	Concentrations	
1	Alaba	1	i	Mancozeb	Copper oxychloride	3.5g/l	3
2	Alaba	2	ii	Mancozeb	Copper oxychloride	0.5g/l	3
3	Alaba	3	iii	Mancozeb	Copper oxychloride	2.4g/l	5
4	Alaba	4	iv	Mancozeb	Copper oxychloride	0.65g/l	5
5	Alaba	5	v	Mancozeb	Copper oxychloride	dn	7
1	Humbo	1	i	Flint	Trifloxystrobin	dn	dn
2	Humbo	2	ii	Flint	Trifloxystrobin	5g/l	5
3	Humbo	3	iii	Flint	Trifloxystrobin	25 g/l	dn
4	Humbo	4	iv	Flint	Trifloxystrobin	1.5 g/l	7
5	Humbo	5	v	Flint	Trifloxystrobin	1.5 g/l	7
1	Mareko	1	i	Anvil	Hexaconazole	8.5g/l	7
2	Mareko	2	ii	Anvil	Hexaconazole	0.5g/l	dn
3	Mareko	3	iii	Volcano	Hexaconazole	dn	dn
4	Mareko	4	iv	Volcano	Hexaconazole	1.75ml/l	5
5	Mareko	5	v	Volcano	Hexaconazole	dn	7
1	Shashogo	1	i	Flint	Trifloxystrobin	dn	7
2	Shashogo	2	ii	Flint	Trifloxystrobin	dn	5
3	Shashogo	3	iii	Flint	Trifloxystrobin	dn	5
4	Shashogo	4	iv	Flint	Trifloxystrobin	dn	5
5	Shashogo	5	v	Flint	Trifloxystrobin	dn	7
1	Arsi negelle	1	i	Bayfidin	Triadimenol	dn	7
2	Arsi negelle	2	ii	Flint	Trifloxystrobin	dn	7
3	Arsi negelle	3	iii	Flint	Trifloxystrobin	dn	5
4	Arsi negelle	4	iv	volcano	Hexaconazole	dn	3
5	Arsi negelle	5	v	volcano	Hexaconazole	dn	7
	Mean						13.7
	SD						5.25

Dn= the respondent does not know

Appendix 4. Chili nursery pest and disease symptoms and common practices in Ethiopia, 2014. Low, Medium, Higher severity, very low severity damage (A, B, C and D)

Figure 4

Appendix 5: Survey Questionnaire

Questionnaire on Knowledge, Prevalence and Importance of Chili Anthracnose in Ethiopia

1. For the Nursery/FTC Personnel

1.1. Region ……………………………………………………………………………

1.2. District……………………………………………………………………………..

1.3. Administrative Post…………………………….……………….……………………

1.4. Location…………………………………………………....………………………

1.5. Date…………………………………………………………………………….…….

1.6. Interviewer………………………………………………………………..…….

1.7. Respondent…………………………………………………………….……….

1.8. How many Chili seedlings (number) are in the nursery now? ....

1.9. For how long (number of days or months) the present seedlings have been maintained in the nursery? ....

1.10. How many (number) of the present seedlings have symptoms similar to those in the Photo above? ……………………………………..……….…………………

1.11. What is the ratio between diseased and healthy seedlings (that is X/Y: X = diseased and

Y = total number of seedlings)…………………………………………………………..

1.11.1. On transplanted seedlings …………………………………………………..……….

1.11.2. On non-transplanted seedlings…………………………………………..…………...

1.12. Are the seedlings watered? (Yes/no). How often (number of times per day or per

Week)………………………………………………………………….……………………

1.13. Are the plots sprayed with fungicides before flowering?

Yes………………………….. No………………..…………………………………………

1.14. If yes, how? ....…………………………………………………………

1.15. What is the effect of spraying? ………………………….

How is the spraying effect measured? ………………………………………………..

1.16. Is there any of the years when you have no seedlings in the nursery? ………………

Which one (from ……… to ……….…)? ……………..……………………………………….

1.17. Are the mother sprayed with chemicals? ……………………………………………

What is the chemical…………………………….………………………….. and

Rate of application ……………………. And

Frequency?……………………………….. …………………………..

Aimed to control (pest and disease names) ……………………………………………………..

1.18. Are the seedlings in the nursery sprayed with any chemical?…………...………..

Which one (name)?…………………….

At which frequency?…………………….. and

which rate of application? ………………………………………………………..

1.19. What is the actual damage of the symptoms observed on seedlings? (Signal the correct answers).

1.19.1. They only defoliate the seedlings………..……………………….……...…..….

1.19.2. They do kill the seedlings……………………………………………….………….

1.19.3. They cause no problem to the seedlings………………………………..………..…

1.20. When (period of months) are the symptoms observed? ……………….…………….

1.21. When do (month) the appearance of new symptoms end?...

1.22. Do nearby adult plants (up to 300 m) show similar symptoms or not?……………….

2. For the farmers and ‘other’ personnel

2.1. Region ……………………………………………………………………………

2.2. District……………………………………………………………………………..

2.3. Administrative Post………………………………………………………………..

2.4. Location……………………………………………………………………………

2.5. Date………………………………………………………………………………..

2.6. Interviewer…………………………………………………………………………

2.7. Respondent………………………………………………………………………...

2.8. When preparing from mature plants, have you ever come across symptoms similar to those illustrated in the photos above?………………………………………………..

2.9. Do such symptoms affect the quality of the chili fruit?…………………..………………..…

2.10. If yes to 2.9, then how do you assess the damage?………………………………….....

2.11. What do you do to minimize the damage?……………………………………………

2.12. Are the matured plants sprayed in order to control these symptoms? ………………

2.13. If yes, what is the chemical, the rate and the frequency of application? ………

2.14. Describe how the seedlings are uprooted from the nursery, packed and transported to the nursery ….……………….…………………………………………

2.15. What basis (criteria) do you use to group the Region, e.g. by size, color, cultivar, quality, Origin, etc . . . .………………………………………...…………………………………